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SAW SCENE

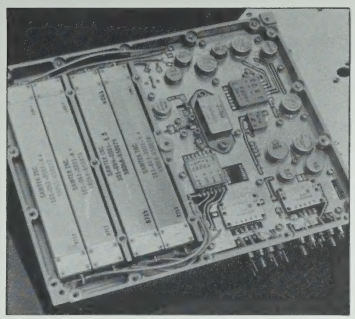
SAW Subsystems
Getting the most from SAWS

Jorgen Andersen

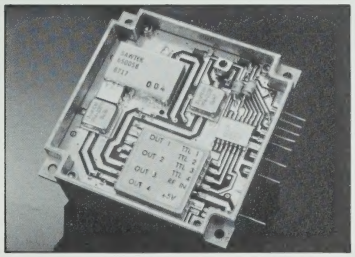
Surface acoustic wave (SAW) devices are powerful and versatile signal processing components. In their many forms, they can be anything from a simple delay element to a passive convolver. SAWs can be designed as finite impulse response filters, resonator filters, and frequency control elements. Dispersive devices are used in pulse compression radar, compressive receivers, and real-time spectrum analyzers.

Great savings over other technologies can be realized in power, size, and weight through the application of SAW devices. However, a number of practical issues make it much easier for manufacturers rather than their customers to develop SAW-based systems. Because of their versatility, SAW transfer and terminal functions vary widely. Few engineers have the opportunity to work with all their variants and, thus, may not be familiar with the vicissitudes of a particular configuration.

In an attempt to provide some guidance in the make or buy decision process, this issue of SAW SCENE will discuss a few of these considerations.



Four-Mode Linear FM Expansion Module for an Airborne Radar



Four-Channel Switched Filter Module

Matching and Noise

By definition, a conjugate match results in equal power dissipated in the source and the load. However, for all practical purposes, a SAW transducer is a capacitor. While it is possible to achieve a conjugate match with the resistive part of the transducer impedance, very often the consequence is inadequate bandwidth. Since a capacitance cannot dissipate power, any attempt to make the transducer look like 50 ohms over non-zero bandwidth will have suboptimal results with respect to signal-to-noise ratio.

The most efficient coupling networks maximize the transducer gain-bandwidth product. Their realizations are analogous to the double-tuned transformer in which one of the tuned windings is unloaded. As such, while they can be designed to operate from and into 50 ohms, they invariably appear reflective to the source or load. This obviously poses a problem in a constant impedance interface. In addition, there is a more subtle implication with respect to noise.

Commonly available low-noise hybrid and MMIC post-amplifiers are frequently used. Through transformation and feedback techniques, the

(Continued . . . Page 2)

New Product Brochure Released

Sawtek recently announced the release of a new brochure for SAW Frequency Control Components. The eight-page, full-color brochure is designed to guide the user in selecting and specifying the appropriate SAW component for frequency control applications. It includes information concerning the theory of SAW resonator operation and provides typical performance parameters for SAW resonators and delay lines. The brochure covers frequency tolerances, including temperature and long-term stability. It also discusses Q, phase noise, loss, spurious suppression, packaging, radiation performance, and power handling.

To obtain your copy of Sawtek's new SAW Frequency Control Components brochure, please contact our Marketing Communications Department at (407) 886-8860.

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(...from Page 1)

amplifier designer attempts to make their noise impedance (the quotient of input noise voltage and noise current) as close to 50 ohms as possible, while providing a good match. However, the SAW coupling network will be highly reflective. The unwary system integrator will be perplexed when he finds the noise floor higher than anticipated.

These interface problems can be solved with amplifiers specifically designed for use with efficient coupling networks.

Sawtek has a growing repertoire of post-transducer amplifier designs, one of which is illustrated in Figure 1. This particular design is used as a SAC (slanted array correlator) post-amplifier. The goal is to transform the open-circuit noise voltage of the transducer-resistive component to the optimum source resistance of the FET. This also, of course, transforms the signal voltage. The cascode configuration serves two purposes:

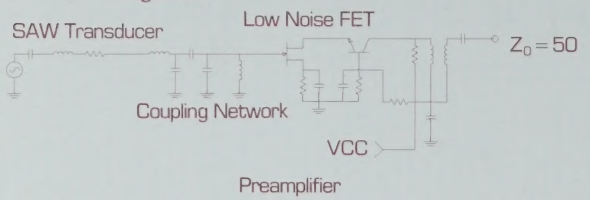
1) Minimizing the Miller effect, the multiplication of the drain to gate feedback capacitance with voltage gain, maintains a high input impedance.
2) Reducing the Miller effect minimizes the input current at higher frequencies by reducing the real part of the output circuit conductance reflected to the input.

The high, almost purely capacitive, input impedance represents an ideal termination for the transducer coupling network.

Figure 2 is a plot of the network frequency response. The voltage transformation is indicated in decibels. The impedance transformation is the voltage ratio squared, thus the nominally 6 ohm transducer resistance becomes 950 ohms, which is the optimum source resistance for the particular FET used. FETs also have the advantage of achieving their optimum noise figure at bias levels consistent with good signal handling capabilities.

Piezoelectric transducers are responsive to applied potential. Therefore, the design criteria for a transducer driver is to maximize the voltage swing uniformly across the band of interest. Using the appropriate coupling network results in efficient driver amplifiers that dissipate very little power.

Figure 1



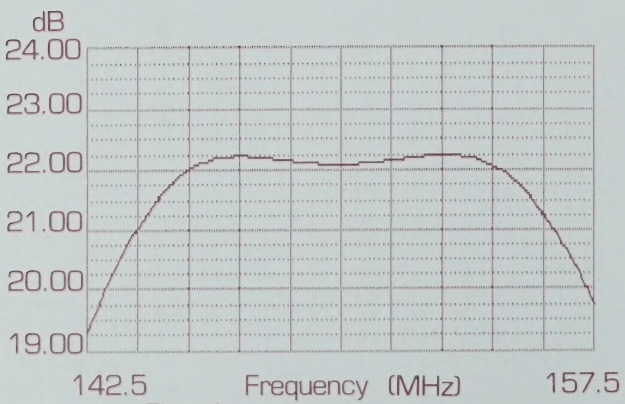


Figure 2

These examples cited are intended only to be indicative of the specialized nature of SAW transducer interface design. The flexibility of the SAW device has lead to a wide variety of transducer characteristics, the discussion of which are beyond the scope of this article.

While anyone familiar with bandpass filter synthesis can readily design an optimal interface, the SAW manufacturer has one critical advantage. The transducer equivalent circuit is available at the time the device is modeled; that is, prior to fabrication.

Modulation and Detection

As bandpass devices, SAWS are almost invariably used in cascade with some form of modulation and detection process. The SAW designer can model the complete baseband-to-baseband channel response prior to fabricating the first device. This clearly reduces technical risk, which the system integrator otherwise would have to assume.

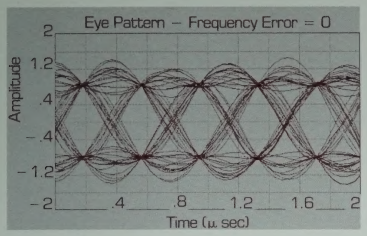
The effects of bandpass tilt, phase non-linearity, and center frequency errors are but a few of the issues that can be studied. Before being committed to a frequency plan, for example, the SAW system engineer can establish the best IF frequency for the SAW filters. Figures 3 and 4 illustrate the effect of center frequency error on digital modulation.

This particular example consists of the convolution of a SAW transmitter Nyquist filter, a SAW matched filter, and pseudorandom BPSK.

Figure 4 clearly illustrates that when the symbol rate is a small fraction of the carrier frequency, center frequency errors become more significant and can cause severe distortion due to the resultant spectral asymmetry.

Another family of SAW devices, the SAW resonator, is an excellent candidate for use in carrier and clock recovery loops. With the SAW-matched filter minimizing the noise bandwidth, squaring losses are also minimized. The resonator filter is used as a ringing circuit, which acts like a phase memory. While this is theoretically unnecessary, practical limitations in commonly used PLL phase detectors result in loss of lock at higher carrier-to-noise ratios than would be the case if a resonator prefilter is used. Since voltage-controlled resonator oscillators can operate through L band, coherent

Figure 3



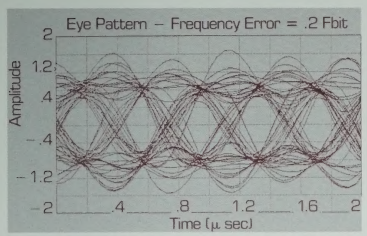


Figure 4

detection can readily be implemented at high IF frequencies, which greatly simplifies receiver design.

Analog communications channels are also readily evaluated with models of SAW filters. Figure 5 shows the intermodulation distortion generated by SAW phase errors. These effects are of interest in video FM, FM frequency division multiplexing, and other wideband angular modulation. The IMD plot serves only as an illustration; video differential gain and phase or FDM noise power ratio can just as easily be quantified. Since the efficacy of FM systems depends in large part on their IF characteristics, a great measure of assurance is provided in scrutinizing these issues prior to commitment to a system configuration.

Hybrid Systems

In an effort to reduce size, weight, and power consumption, hybrid integration is now being heavily pursued. These hybridized subsystems, often referred to as "supercomponents", are used to add features to existing avionic platforms where space is already at a premium.

Common examples of hybridized SAW subsystems being produced today are SAW oscillators and SAW filter banks. It is not unusual for hybrid SAW oscillators to integrate other functions such as multiple isolated RF ports, frequency multiplication stages, and built-in test capabilities.

When the SAW user attempts hybrid integration himself, he is required to expand his normal systems integration effort to include a host of SAW-related issues which require a knowledge of other disciplines.

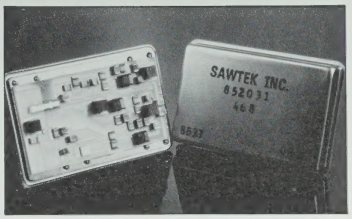
The SAW designer needs to be versed in the subtleties of material and process variables which effect both thermal and long-term stability. For instance, it is not unusual for Sawtek oscillator engineers to compensate for the temperature coefficient of other components in an oscillator feedback loop by adjusting the crystallographic cut of the SAW substrate.

In applications requiring precision frequency adjustment, it is not uncommon for the SAW manufacturer to select SAW die during the RF probing operation to accommodate other varying component parameters.

The long-term frequency stability of SAW devices is very much determined by the out-gassing characteristics of hybrid manufacturing materials. SAW manufacturers have the experience to deal with these problems and know which materials to use and which to avoid.

In some cases, where precision frequency tolerance is required, it may also be necessary to implement in-situ frequency trimming of the mounted SAW device. Such tuning techniques are highly specialized processes specific to SAW manufacturing.

The mechanical and thermal properties of SAW die bonding materials can induce stress which will, in turn, interact with the SAW acoustical properties. This subtle and often underrated materials selection problem is a critical factor in determining the yield of the phase-matching requirements for filter banks.



468 MHz Hybrid SAW Oscillator

Advantages of SAW-based Systems

SAW manufacturers have three major advantages in the design and fabrication of SAW-based systems.

First, having device models permits the study of system level performance prior to fabricating either the devices or system. This greatly reduces risk. Since these models are considered highly proprietary, it is not likely they will become widely available.

Secondly, a SAW house has an inventory of modules and standard circuits optimized for use with SAW devices.

Finally, due to the need to handle and mount unpackaged devices, SAW hybrids should be constructed by the device manufacturer.

If you are considering SAW technology for your application, please contact Sawtek at the conceptual design phase, if possible. Our experienced SAW systems engineers can guide you in specifying the device or subsystem appropriate for your application. Such informal dialogue often results in substantial cost/ performance improvements in the user's system. ■

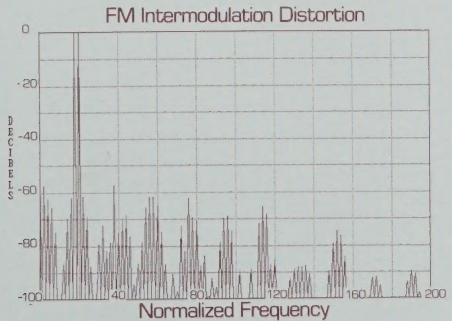


Figure 5

About the Author

Jorgen Andersen joined Sawtek in 1988 as Systems Group Leader from Alpha Industries where he was Chief Engineer for the Telecommunications Operation.

For the past 15 years, Mr. Andersen has been involved in digital communications as well as pulse compression systems. This experience and his career-long interest in SAW signal processing, frequency synthesis, and phase-lock design provides a strong foundation for his leadership role in SAW system design at Sawtek.

In addition, Mr. Andersen has received several patents and published papers for his area of expertise. He most recently co-authored the technical paper, "Custom Subsystems and Fully Integrated Hybrid Modules", on which this SAW SCENE article on SAW subsystems is based. ■

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